# Distance Visibility Algorithm (DiVA) Transition

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## LONG-TERM GOALS

The immediate goal of this project is to develop a robust and viable method for estimating underwater visibility that will aid Navy mine hunting efforts in actual operation. The overall long-term goal is to transition this method, called DiVA (Distance Visibility Algorithm), to the operational Navy.

## OBJECTIVES

There are three major objectives of this DiVA transition effort: 1) Conduct diver visibility experiments in a range of optical water types to obtain a database for testing and refining the DiVA model; 2) Provide to the Navy a fully documented DiVA model that can be independently tested and validated; 3) Develop and deliver a real-time, stand-alone computer program for processing in-situ data and providing graphic and numeric output of visibility range.

## APPROACH

The Navy has several types of optical mine-hunting systems, including divers, that are deployed from ships. It is highly desirable, and in some cases critical, for the Navy to have accurate performance predictions of these systems prior to deployment. The DiVA method is designed to provide the operators, in real time, with accurate system performance estimates based on actual measurements of water optical properties. Real-time in-situ optical measurements are feasible since at least one ship is already on station – the ship that deploys the mine-hunting system. Prior to deploying this system, a rapid profile of the water column is performed using a robust, self-contained, simple to deploy instrument that measures the necessary optical properties for estimating system performance. Two instruments have been developed for this purpose, *a*-βeta and *c*-βeta. *a*-βeta measures the diffuse attenuation, absorption, and backscattering coefficients and *c*-βeta measures the beam attenuation and backscattering coefficients (Dana and Maffione, 1998).

As soon as a profile is completed, the *a*-βeta and *c*-βeta measurements are fed into the Distance Visibility Algorithm (DiVA) which then computes a profile of the maximum visibility, or target acquisition distance for divers or a particular imaging system. The DiVA, which was developed on this project, is an analytical algorithm that computes image contrast as a function of range and, inversely, maximum visibility distance as a function of (minimum) image contrast threshold. A depth profile of maximum visibility range is then provided to the appropriate Navy personnel who can use

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**The immediate goal of this project is to develop a robust and viable method for estimating underwater visibility that will aid Navy mine hunting efforts in actual operation. The overall long-term goal is to transition this method, called DiVA (Distance Visibility Algorithm), to the operational Navy.**

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this information to decide on appropriate search methods or whether a system should be deployed at all.

**WORK COMPLETED**

HOBI Labs has developed a Distance Visibility Algorithm, DiVA, that rapidly computes both image contrast as a function of range and the maximum visibility distance for divers and underwater camera systems using either active or ambient lighting conditions. DiVA is a mathematically rigorous model derived from radiative transfer theory. To compute visibility distance, three in-situ measurements are needed, $a$, $c$, and $K_L$, the absorption, beam attenuation and target radiance attenuation coefficients respectively. These optical variables are measured with the $a$-βeta and $c$-βeta instruments. In addition to measurements of the input optical variables, DiVA requires a parameters table that is determined by regressions to numerical solutions of the radiative transfer equation. We have completed the RTE modeling effort and produced a robust parameters table. We have also completed the development of a computer program that incorporates this table and computes and displays distance visibility profiles from measured profiles obtained with the $a$-βeta and $c$-βeta instruments. We have conducted a number of diver visibility experiments in Monterey Bay to compare actual measurements of diver visibility to those predicted by DiVA. DiVA was presented to a team at NRL-Stennis and ONR who will be working on its transition to the operational Navy. A final report has been delivered.

**RESULTS**

The DiVA mathematical model is described elsewhere (Maffione 2002a, 2002b). One form of the algorithm gives the target contrast $C$ as a function of range $R$ and can be expressed succinctly by

$$C_H(r) = \frac{C_0}{1 + \frac{2\Lambda}{K_L}\left[\exp(K_L r) - 1\right]}, \qquad (1)$$

where $C_0 = C(R{=}0)$ is the inherent contrast of the image. $K_L$ is the target radiance attenuation coefficient (estimated by $a$-βeta and $a$-βeta measurements) and $\Lambda$ is referred to as the “lighting” factor. This factor is the only free parameter in the model and is determined by from a look-up table.. This table was produced by numerically solving the RTE and performing polynomial regressions to the results. The table has been shown to be a very accurate and robust solution to the radiative transfer variables that are explicit variables in $\Lambda$ (Maffione, 2002a,b). Solving Eq. 1 for the maximum visibility distance, the DiVA is given by

$$R_H = \frac{\ln\left[\frac{K_L\left(C_0/C_m - 1\right)}{2\Lambda} + 1\right]}{K_L}. \qquad (2)$$

where $C_m$ is the contrast threshold (usually taken to be between 0.02 and 0.05). Note that this equation is for horizontal visibility. There is a slight modification to this equation for vertical variability (Maffione, 2002a,b).

In addition to developing the DiVA model and developing a computer program that performs the visibility computations, we conducted in-situ experiments to compare the DiVA predictions to actual

diver visibility measurements. Figure 1 shows an underwater picture of the experimental arrangement. Basically, one diver holds a target while a second diver takes digital photographs of the target at various distances, while *a*-βeta and *a*-βeta measurements are made simultaneously at the depth of the target.. Target contrast is then computed as a function of range from the digital images. The diver notes the actual distance at which the target can no longer be discerned and this is compared with the DiVA calculation. Figure 2 shows a graph of target contrast as a function of range measured in situ by the divers, along with the computation of target contrast from the DiVA model, Eq. 1. Note the excellent agreement. (Field data have not been submitted to a national archive.)

## IMPACT/APPLICATIONS

Understanding underwater visibility has been an important subject of investigation for many decades. Because DiVA is the first underwater visibility model that has been tested and validated, it will no doubt have a profound impact on both the science of understanding underwater visibility and on underwater imaging systems. DiVA may provide the key model to properly interpreting the huge database of Secchi depth measurements in terms of inherent optical properties. For the operational Navy, DiVA has the proven potential for providing critical information to divers and operators of mine-hunting systems.

## TRANSITIONS

DiVA was demonstrated to the Navy for the first time during the GOMEX / MIREM 99 and FBE-HOTEL mine-hunting exercises and the results were used in real-time by two mine-hunting systems, the SLQ-48 and a laser-line scanning system. The DiVA method and results from these exercises are currently being used by NRL scientists who are investigating underwater visibility problems. These personnel include Robert Arnone and Alan Weidemann (Stennis). DiVA is currently undergoing a rapid transition study being conducted by these NRL personnel and others.

## RELATED PROJECTS

1 – The *a*-βeta and *c*-βeta instruments are being used by Robert Arnone's group at NRL as part of their underwater visibility work and they will undoubtedly be conducting their own tests of DiVA.

2 – The *a*-βeta and *c*-βeta instruments are being used by Mike Contarino and Linda Mullen (NAWC) on their project to develop new lidar technology for measuring water-column optical properties and detecting submerged targets.

3 – The *a*-βeta and *c*-βeta instruments were used by CSS (in collaboration with Mike Strand) during the deployment of their laser-line scan system on the CoBOP program in the Bahamas.

4 – I am working closely with program managers to further demonstrate the utility of DiVA to the Navy and eventually transition it to the fleet.

## REFERENCES

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**PUBLICATIONS**

Maffione, R.A., 2002. A new underwater visibility model, *Appl. Opt*. (submitted).

***Figure 1. Underwater photograph of divers measuring the contrast attenuation of a target as a function of distance. The instruments on the left are a pair of a-βeta and c-βeta sensors.***

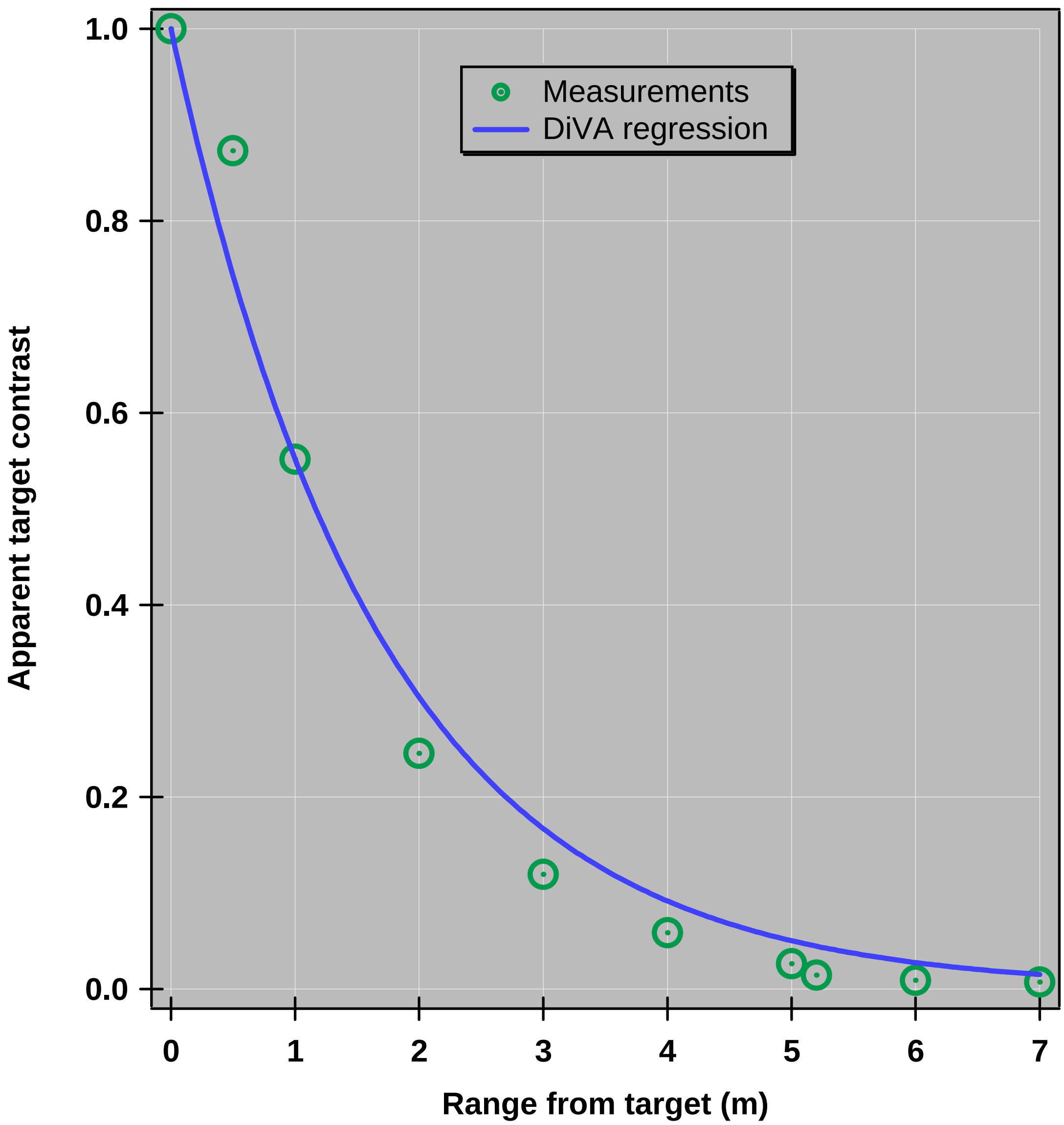


***Figure 2. One example of the results of the underwater contrast measurements and their comparison of apparent contrast predicted by DiVA. Circles are measurements and the solid line was computed from the DiVA.***